# Electrical Characteristics of $Al_2O_3/TiO_2$ Nanolaminate Dielectrics on GaN

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## Introduction

For the future high-speed, low power nano-electronic devices, III-V compound semiconductor devices have high potential to develop [1]. Gallium nitride (GaN) MOSFET is of importance due to GaN extraordinary material properties, like high saturation velocity (~$3\times10^7$ cm/s at 150 kV/cm) [2], high critical electric field, and high thermal conductivity [3]. Moreover, the wider energy band gap of GaN could reduce the drain-induced barrier lowering and band-to-band tunneling [4]. For developing III-V MOSFETs, various oxide materials were used as the gate insulator. In this report, a multilayer dielectric nanolaminate of $Al_2O_3/TiO_2/Al_2O_3$ was used as the gate oxide. This stack combines the high band gap $Al_2O_3$ (8.8 eV) to prevent the thermal ionic emission [5] with the high dielectric constant of $TiO_2$ ($k \sim 50-80$) to provide higher drive current [6][7].

## Experiments

The as-deposited nanolaminate $Al_2O_3/TiO_2/Al_2O_3$ stack with thicknesses of 2.5/5/2.5 nm was deposited with a RF sputtering system. Oxygen ($O_2$) annealing and postmetallization annealing (PMA) were tried to reduce defects and leakage current density in the temperature range of 350~550$^{O}$C. A MIM capacitor with the same nanolaminate $Al_2O_3/TiO_2/Al_2O_3$ stack was fabricated with a TaN/Ta bottom electrode and an Ir top electrode. The capacitance was measured by precision LCR meter at 1 MHz.

## Results and Discussion

In Fig. 1, the leakage current density of nanolaminate $Al_2O_3/TiO_2/Al_2O_3$ stack decreases with $O_2$ annealing temperature and can reach $9.6\times10^{-11}$ A/cm$^2$ at 1V and $2.2\times10^{-9}$ A/cm$^2$ at -1V at 500$^{o}$C, respectively. The leakage current density slightly decreases after PMA as shown in the inset. The C-V characteristics were almost independent of $O_2$ annealing temperature. However, the C-V characteristics were improved with the PMA temperature from 550$^{O}$C to 650$^{O}$C for a time period of 10 min. as shown in Fig. 2. The hydrogen atoms from PMA process can passivate the defects in the films and reduce the interface states. The capacitance is $3.33\times10^5$ pF/cm$^2$ after $O_2$ annealing at 500$^{o}$C. After optimum 600$^{o}$C PMA, the capacitance can reach $1.03\times10^6$ pF/cm$^2$, which is 3 times larger. The effective oxide thickness ($\varepsilon_{ot}$) after 600$^{o}$C PMA treatment decreases to 3.3 nm. Figure 3 shows the capacitance of the MIM capacitor. The *k* value is 13.56 and the $\varepsilon_{ot}$ is 2.8 nm.

## Conclusion

The nanolaminate $Al_2O_3/TiO_2/Al_2O_3$ stack on GaN shows ultra low leakage current under high temperature $O_2$ annealing and high dielectric constant after PMA. It shows high potential for the fabrication of GaN MOSFET.

## References

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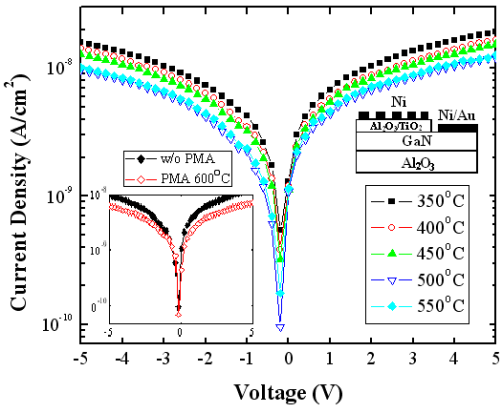


Fig. 1 J-V characteristics as a function of $O_2$ annealing and PMA temperature.

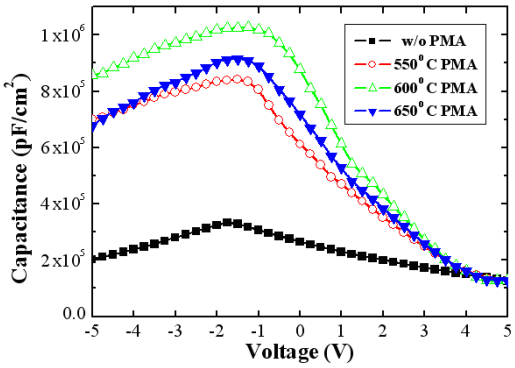


Fig. 2 C-V characteristics as a function of PMA temperature were measured at 1 MHz.

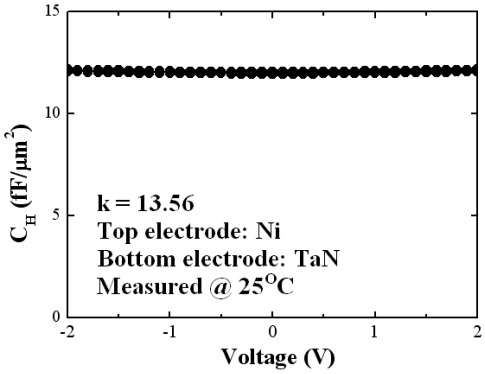


Fig. 3 C-V characteristic $Al_2O_3/TiO_2/Al_2O_3$ MIM capacitor after 600$^{o}$C PMA.